

WORLD WEATHER PROGRAM

The Department of Commerce (DOC) was designated by the President, following Senate Concurrent Resolution 67 (1968), to be the lead agency for coordinating United States participation in the World Weather Program (WWP). Until 1983, DOC published a separate report on WWP Plans. Beginning with the 1983 edition of the *Federal Plan for Meteorological Services and Supporting Research*, a section on the WWP has been included, obviating the need for a separate report. The last segment of this narrative includes information on bilateral and regional international cooperative activities which are not under the WWP.

GOALS AND ORGANIZATION

The World Weather Watch (WWW) goals are to extend the time, accuracy, range, and scope of weather prediction and to understand the physical basis of climate and climatic change. The ability of the United States and other nations to use their existing scientific capability to understand the climate and to increase their weather predicting skills is limited by the lack of global weather data. Available weather data are inadequately observed over a significant portion of the Earth's surface, especially over isolated areas including the oceans.

Development of the technology and the systems to obtain these observations, especially over the oceans, presents formidable problems. With the use of satellites, aircraft, ships, radar, anchored and drifting buoys, and balloons, however, an integrated system can be developed to observe and collect comprehensive data about the atmosphere over the entire globe. This system is too complex and expensive to be implemented by a single nation--a fact clearly recognized by the leaders of many nations whose international cooperation in meteorology has been a tradition for more than a century. In 1961, this continuing need for international cooperation prompted the President of the United States to propose to the United Nations (UN) the establishment of an international effort in weather prediction. The UN responded by calling upon the World Meteorological Organization (WMO) and the International Council of Scientific Unions (ICSU) to develop

measures to improve weather forecasting capabilities and to advance the knowledge of the basic physical forces that determine climate.

The WMO, with 185 Members, is an intergovernmental organization affiliated with the UN to facilitate international cooperation in the fields of meteorology, climate, and operational hydrology. The WMO responded to the UN request with the concept of the World Weather Watch, an operational system to bring the global atmosphere under improved surveillance and to provide for the rapid collection and exchange of weather data as well as for the dissemination of weather products from centralized processing centers.

More recently, the WMO is working towards the design and implementation of improved observations for a Global Climate Observing System (GCOS) through enhancements to the Global Observing System (GOS) and other appropriate measures. These efforts are expected to yield an enhanced GOS for both operational and research purposes and are part of the effort to strengthen the WMO's commitment to improve the understanding of climate and related environmental matters, as articulated by the Second World Climate Conference in 1990 and repeated at the UN Conference on the Environment and Development.

The responsibilities of United States federal agencies in the WWW are as follows:

- Department of Commerce (DOC). Represents the United States at WMO and, through the National Oceanic and Atmospheric

Administration (NOAA), provides the focal point to coordinate the United States' efforts in these international programs, implements those service improvements in the existing international weather system for which the United States accepts responsibility, and develops new technology.

- Department of State (DOS). Maintains relations with developing nations and, through NOAA and the WMO, assists developing nations in improving their national weather services. DOS also develops appropriate multilateral and bilateral arrangements to further international participation.
- National Science Foundation (NSF). Stimulates and supports basic research by non-government scientists on atmospheric and ocean circulations and modeling. It also promotes the education and training of atmospheric and ocean scientists at universities.
- Department of Defense (DOD). Although the mission of DOD weather services is basically internal, the nature of DOD's operations is global. As such, the observation, telecommunications, and data-processing programs of the military weather services provide significant indirect support to the WWW through DOD's interface with NOAA's National Weather Service (NWS). Information from the research and development activities of these services is exchanged routinely with other similar national agencies and is often presented at national forums.

- Department of Transportation (DOT). Through the United States Coast Guard, provides personnel to support NOAA's National Data Buoy Center (NDBC) in developing, operating, and evaluating data buoy systems. Coast Guard cutters and aircraft provide operational support to deploy, service, and retrieve buoys built for test or operational purposes. DOT's observation and telecommunications programs also provide significant indirect support to the WWW through DOT's interaction with the NWS.
- National Aeronautics and Space Administration (NASA). Performs research, develops aerospace technology required for an effective global weather system, and provides data from R&D satellites to the WWW.

THE WORLD WEATHER WATCH

The WWW is an integrated services system which functions on three levels--global, regional, and national. The WWW is divided into three essential elements that are closely linked and interdependent--the Global Data Processing System (GDPS), Global Telecommunication System (GTS), and GOS.

These elements are coordinated and closely integrated through three WWW support functions: (1) the data management function coordinates, monitors, and manages the flow of data and products within the WWW system to assure their quality and timely delivery. It also includes the definition and use of code forms for data exchange; (2) the systems support activity provides guidance, technical and scientific information, and training to those involved in the planning, development, and operation of WWW components; and (3) the implementation and coordination function assures the timely completion of the WWW implementation and effective support and maintenance of the WWW system.

Global Observing System

The GOS is a coordinated system of methods, techniques, and facilities for making meteorological observations on a worldwide scale. It is a composite system containing surface-based and space-based (satellite) subsystems. The main elements of the subsystem are:

- Regional, basic-synoptic networks, staffed and automated, for both surface and upper-air observations.
- Fixed observing stations at sea, composed of fixed and anchored platform stations, and island and coastal stations.
- Mobile sea stations, including moving ships.
- Moored and drifting buoys.
- Aircraft meteorological stations, including automated aircraft reporting systems.

The space-based (satellite) subsystem provides vital support for meteorological and hydrological predictions and warnings. The use of satellites enables the routine collection of environmental observations from even the most remote locations. Two categories of satellites are used: polar orbiters and geostationary.

Presently, operational meteorological satellites in polar orbits are operated by Russia (the METEOR-3 series) and the United States. The United States operates the civilian NOAA Polar-orbiting Operational Environmental Satellite (POES) series along with the Defense Meteorological Satellite Program (DMSP) series of polar-orbiting spacecraft. NASA currently launches satellites for NOAA, alternately, into afternoon and morning orbits to maintain an uninterrupted stream of global data. The current primary operational NOAA polar-orbiting satellites are NOAA-16 (launched in an afternoon orbit in September 2000) and NOAA-15 (launched in a morning orbit in May 1998). The current primary operational DMSP polar-orbiting satellites are F-15 (launched in

December 1999) and F-14 (launched in April 1997). Also, China is operating its first generation FY-1C satellite launched in May 1999 in sun-synchronous morning orbit.

Preparations continue with the Europeans for their assumption of NOAA's morning polar orbit mission starting with the launch of Metop-1 in 2005. This complements United States plans to merge NOAA's POES with the DMSP to form an integrated system called the National Polar-orbiting Operational Environmental Satellite System (NPOESS) that is expected to fly at the end of this decade. NOAA, DOD, and NASA are working together to implement NPOESS in the context of an Integrated Program Office (IPO). NOAA heads the IPO and is responsible for operating the NPOESS and for relations with national and international civilian users of the system. DOD has the lead responsibility for NPOESS acquisition, launch, and system integration. NOAA will facilitate the development and incorporation of new, cost-effective technologies to enhance the NPOESS capabilities.

Operational geostationary weather satellites are currently operated by Japan, India, the United States, and the European Organization for the Exploitation of (EUMETSAT). Japan's Geostationary Meteorological Satellite (GMS) is positioned at 140° East, India's Indian National Satellites (INSAT) are at 74° East and 83° East, and EUMETSAT's METEOSATs 7 and 5 are at 0° and 63° East. The United States operates two Geostationary Operational Environmental Satellites (GOES) - at 75° West and 135° West. GOES-8, launched in April 1994, is operational at 75° West and GOES-10, launched in April 1997, is operational at 135° West. China also launched its first pre-operational geostationary environmental satellite FY2A on June 10, 1997, and its second FY2B in January, 2001.

FY2B is located at 105° East and FY2A was moved to the backup position at 85.6° East.

Broadcast of data from both the NOAA and GOES series of United States satellites is free, unrestricted, and does not require any prior notification. Data can be received directly by any properly-equipped ground station within the satellites' line-of-sight. The United States, through NOAA, develops information and products from these data for further distribution over the GTS.

The WWW is a flexible system which can be adapted to changing technology and operational conditions. The latest technological and scientific developments in observations, data processing, and telecommunications are under constant review with an eye towards improving the GOS, GDPS, and GTS.

Over the last few years, several systems intended to improve the operation of the GOS have continued to undergo development and deployment. Among these systems is the family of automated aircraft reporting systems known as the Automated Meteorological Data and Reporting (AMDAR) systems. This family of systems includes the Aircraft to Satellite Data Relay (ASDAR) system and the ARINC Communications Addressing and Reporting System (ACARS). ARINC is Aeronautical Radio Incorporated - a wholly owned subsidiary of the airlines. ASDAR uses a dedicated on-board processor connected to the aircraft avionics system and transmits observations automatically via the meteorological geosynchronous satellites of the International Data Collection System (IDCS). ASDAR uses hardware which was developed in the 1980's and was fitted to the aircraft, requiring relatively expensive and time-consuming certification and installation. It has the important advantage of using the meteorological satellite communications facility

which is free for this type of message. On the other hand, ACARS uses the plane's own avionics system thus requiring no certification or alteration to the airframe. It does, however, use the airlines' communications system which could entail communication costs.

The ASDAR program has continued to provide valuable observations over data sparse regions of South America, the central and southern Atlantic Ocean, Africa, the Indian Ocean, Asia, and Eastern Europe. Much of this area is otherwise not covered by any *in-situ* upper air observations. However, this situation is expected to change in the near future as many of the existing ASDAR equipped aircraft will be converted or replaced by other aircraft fitted with conventional AMDAR systems. The program peaked early in 1998 with 21 operational systems. However, since then there has been a substantial reduction in the size of the ASDAR program. This was accomplished in 2 phases with the first 5 British Airways 747 aircraft decommissioned between October 1998 and August 1999 and the second and final 5 aircraft between January and June 2000. These same aircraft have been fitted with AMDAR software along with 45 other aircraft in the B747-400 fleet. KLM decommissioned the first of its 3 operational units in April 2001.

Although the program is in decline, several units have a priority and should be kept operating for a few more years as they will still form the main source of aircraft observations in critical data void areas. These include units on aircraft from Air Mauritius (2), KLM (2) and Aerolineas Argentinas (2). The South African units (2) will eventually be replaced by AMDAR systems as will be the 2 units operated by Saudi Arabia, but not for at least another year.

During the second quarter of 2001, data availability indicates 93.3 percent of observations were received within

60 minutes and 99.5 percent within 115 minutes. An average of 994 reports per day were received. Concerns regarding data quality of some aircraft, particularly in temperature, are being addressed.

The United States AMDAR program, called Meteorological Data Communications and Reporting System (MDCRS), began in the early 1980's and is a cooperative effort among ARINC, the NWS, and the FAA. It grew slowly in the first 10 years, but has grown rapidly during the decade of the 1990's. Over 120,000 reports of wind and temperature are sent every day in the Binary Universal Form for Representation of Meteorological Data (BUFR) code. These MDCRS reports are provided by six airlines: Delta, Northwest, United, United Parcel Service (UPS), American Airlines, and Federal Express (FedEx).

Two additional MDCRS reporting elements continue under development: water vapor and turbulence. A new water vapor sensor, using diode laser technology is being tested. This new sensor will replace the current version being flown on 30 UPS B-757 aircraft as part of a demonstration program. Ultimately, this new technology is hoped to be flown operationally on commercial aircraft. A new turbulence algorithm, developed by the National Center for Atmospheric Research (NCAR) derives an objective, aircraft independent measure of turbulence (eddy dissipation rate-EDR) from aircraft vertical acceleration. The EDR is included as part of the MDCRS data stream. The algorithm is currently installed on 90 United Airlines aircraft and will be installed on over 400 United, American, Delta, and Northwest aircraft by FY 2003.

Large quantities of weather reports, particularly over oceanic and other data-sparse areas, will be realized via satellite communications and navigation systems. This source of data is of

interest to the United States and others of the international aeronautical community, especially Numerical Weather Prediction (NWP) Centers including World Area Forecast Centers (WAFCs).

The Forty-Ninth Session of WMO's Executive Council (Geneva, June 1997) established a Panel on Aircraft Meteorological Data Reporting composed of WMO Members that operate, or intend to operate, national AMDAR programs and to coordinate and promote global AMDAR development. Several countries have developed AMDAR programs of their own, focused on obtaining aircraft data over data sparse areas, including South Africa, Hong Kong, Russia, Saudi Arabia, and the Caribbean.

In addition to these aircraft-based systems, other observation systems are being deployed to improve the GOS. For example, there has been deployment of substantial numbers of drifting buoys. A number of nations, including the United States, have implemented experimental or quasi-operational networks or single sites of ground-based doppler radars called wind profilers to provide nearly continuous wind soundings. A network of 32 tropospheric wind profilers is being operated quasi-operationally at 404 MHz primarily in the central part of the United States.

To improve the methodology used in developing and deploying observing systems, NOAA in 1997, established the North American Atmospheric Observing System (NAOS) program. The group has representatives from several federal agencies along with representatives from Canada and Mexico. NAOS objectives are to: (1) define a cost-effective, requirements-driven "best mix" of observing platforms and instruments and (2) reduce observing system risks and uncertainties. While the initial focus of the program will be to modernize the composite upper-air network, NAOS is expected to guide the

resource-allocation process for most future observing systems developed and/or fielded by NOAA. Several projects of NAOS have been undertaken to assess the utility of the MDCRS data in numerical models, including the impact of replacing some numbers of rawinsonde sites with MDCRS soundings, an assessment of forecaster use of MDCRS, and the impact on short-range forecasting.

Efforts are underway to design and implement a GCOS, building upon the WWW, Global Atmospheric Watch, Integrated Global Ocean Services System, and other existing systems to further the knowledge and understanding of climate and the prediction of climate and climate change. Efforts to date have established planning groups to address needs and requirements for atmospheric, oceanic, and land-surface data. Upper-air and surface-observing networks have been defined to provide basic global measurements for the GCOS. Links to existing organizational structures are being established and a high priority has been given to making observational enhancements. The GCOS Upper Air Network (GUAN) and the GCOS Surface Network (GSN) have been established.

Global Data Processing System

The purpose of GDPS is to make available all processed information required for both real-time and non-real-time applications. GDPS provides products and processed information, based on recent advances in atmospheric science, using powerful numerical computer methods. Members have real-time, unrestricted access through the GTS to GDPS products which allow all countries to benefit from their participation in the WWW.

The GDPS is organized as a three-level system. It consists of World Meteorological Centers (WMC), Regional/Specialized Meteorological Centers (RSMC), and National Meteorological Centers (NMC). NMCs carry out GDPS functions at the

national level. In general, real-time functions of the system involve pre-processing of data including real-time quality control, analysis, and prognosis, including derivation of appropriate meteorological parameters. The non-real-time functions include data collection and archival, and additional quality control, storage, and retrieval, to include cataloging observational data and processed information for operational and special applications and for research.

WMCs are located in Melbourne, Moscow, and Washington; they provide guidance products used for general short, medium, and long-range weather forecasts on a global scale. Melbourne specializes in forecast products for the Southern Hemisphere.

The RSMCs with geographical specialization are located at Algiers, Algeria; Antananarivo, Malagasy; Beijing, China; Bracknell, United Kingdom; Brasilia, Brazil; Buenos Aires, Argentina; Cairo, Egypt; Dakar, Senegal; Darwin, Australia; Jeddah, Saudi Arabia; Khabarovsk, Russia; Lagos, Nigeria; Melbourne, Australia; Miami, Florida; Montreal, Canada; Moscow, Russia; Nairobi, Kenya; New Delhi, India; Novosibirsk, Russia; Offenbach, Germany; Rome, Italy; Singapore; Tashkent, Uzbekistan; Tokyo, Japan; Tunis, Tunisia; Washington D.C., United States; and Wellington, New Zealand.

RSMCs with activity specialization are found at the European Center for Medium Range Forecasts; Réunion Island (France); Toulouse, France; Miami, Florida and Honolulu, Hawaii, United States; and Nadi, Fiji.

The regional centers at Bracknell, Miami, Montreal, New Delhi, and Tokyo have dual geographical and activity specialization responsibilities. These centers provide regional products used for short and medium-range forecasting of small, mesoscale, and large scale meteorological systems by WMCs. Products of RSMCs can be

used by members at the national level for further processing or interpretation to provide assistance or service to users.

In the World Area Forecast System (WAFS), two centers (Washington and London) are designated by the International Civil Aviation Organization (ICAO) as World Area Forecast Centers (WAFS) and act as back-up for one another. They issue upper-wind and temperature forecasts with global coverage to associated Regional Area Forecast Centers (RAFC). The regional centers also prepare and distribute forecasts of weather elements defined by ICAO as significant. The RAFC's are expected to be phased out in 2002, when the WAFSs assume their responsibilities.

The gradual implementation of the final phase of the WAFS has begun. The planned final phase call for the two WAFSs to prepare and issue computer-based wind and temperature forecasts as they now do. In addition, those centers will automate all of the significant weather elements. While some of these elements are now prepared automatically, others are developed through forecaster-initiated graphic interaction.

The dissemination of aeronautical information via global satellite broadcast began in 1995. The United States provides the links to two of the three satellites specified in the system.

Global Telecommunication System

The GTS provides communication services for the collection, exchange, and distribution of observational data and processed information among the WMCs, RSMCs, and NMCs of the WWW to meet the member needs for real-time or quasi-real-time exchange of information for both operational and research purposes. The GTS also supports other WMO programs, joint programs with other inter-national organizations, and environmental programs as decided by the WMO Congress and is organized on three levels:

- The Main Telecommunication Network (MTN).
- The Regional Meteorological Telecommunication Networks (RMTN).
- The National Meteorological Telecommunication Networks (NMTN).

The GTS is supported by the telecommunications functions of the WMCs, Regional Telecommunications Hubs (RTH), RSMCs, and NMCs.

The MTN links the WMCs at Melbourne, Moscow, and Washington with the RTHs at Algiers; Beijing; Bracknell; Brasilia; Buenos Aires; Cairo; Dakar; Jeddah; Maracay, Venezuela; Nairobi; New Delhi; Norrköping, Sweden; Offenbach; Prague; Rome; Sofia; Tokyo; Toulouse; and Wellington. It ensures the rapid and reliable exchange of observational data and processed information required by the members.

The RMTNs consist of an integrated system of links which interconnects RTHs, NMCs, and RSMCs to WMCs. The RMTNs provide for the collection of observational data and the selective distribution of meteorological information to member nations.

In summary, the GTS enables the NMCs to receive and distribute observational data and meteorological information to meet the requirements of members. Ongoing WWW activities include:

- GTS network redesign to take into consideration new technical opportunities, such as Internet-like services.
- Improvement of the capacity of MTN links and inclusion of graphics (e.g., Washington-Brasilia, Washington-Buenos Aires, Washington-Tokyo).
- Continued implementation of satellite-serviced data collection platforms to enhance the collection of meteorological data from upper-air and surface-observing sites.
- Continued implementation of satel-

lite direct-readout stations that are compatible with polar-orbiting satellites and the weather facsimile (WEFAX) component of the geostationary satellites. The need to convert WEFAX to LRIT and APT to LRPT formats will have to be undertaken during the next decade.

Voluntary Cooperation Program (VCP)

From the beginning of WWW, it was clear that all countries need better weather observations and improved communications systems. To help remedy deficiencies and to fully implement the WWW, the WMO established a Voluntary Assistance Program in 1967. In 1979, the name of the program was changed to Voluntary Cooperation Program (VCP).

The WMO-VCP helps the developing countries to implement the WWW program by providing equipment, services, and long-term and short-term study fellowships. Since the inception of the VCP, the United States has provided short-term fellowships in electronics, communications, operation and maintenance of weather data collection systems and electrolytic hydrogen generators, and tropical meteorology and river flood forecasting to students from more than 50 countries. Long-term fellowships, through which the students receive baccalaureate or advanced degrees, have been completed by candidates from over 48 countries. The goal of VCP is to eliminate deficiencies in global observations and communications. The highest priority of the VCP is the implementation of the WWW.

The DOS provides funding for VCP projects with NOAA administering and carrying out programs designed to aid meteorological/hydrological and climate projects in recipient countries.

VCP Projects for 2001 include:

- Implementation and updating of surface and upper-air observational programs in the tropics, the Southern Hemisphere, and Africa as resources and priorities permit.

- Support of WAFS applications and utilization.
- Continued support for the implementation of VCP projects in Central America and the Caribbean areas in support of the hurricane and tropical storm programs.
- Connecting National Meteorological Services to the Internet as a low-cost way to collect and enhance a global data base.

BILATERAL AND REGIONAL INTERNATIONAL COOPERATIVE PROGRAMS

United States - Peoples Republic of China Protocol in the Field of Atmospheric Science and Technology

For more than 20 years, this Protocol has covered a broad area of research and operational activities in the field of atmospheric science and technology. Program areas include the following:

- Climate Studies (which includes scientific experiments and research

on monsoons and Tropical Ocean Global Atmosphere).

- Mesoscale Meteorology (which includes operational techniques for forecasting torrential rains).
- Training and Participation.
- Atmospheric Chemistry.
- Satellite Meteorology and Meteorological Satellites.
- Modernization Activities.

The cooperative activities between the United States and China under this program have decreased over the past few years. The main cooperative activity has been within the Training and Participation Program with a dozen Chinese scientists and trainees working at NOAA facilities for up to 18 months.

United States-Mexico Meteorological and Hydrologic Program

The United States and Mexico have signed a cooperative agreement to enhance the scope of their cooperation in the fields of meteorology, hydrolo-

gy, and climatology which began over 50 years ago. The new agreement facilitates the following activities:

- The international dissemination of observations from meteorological and hydrologic observation systems.
- The exchange of meteorological, hydrologic, and related data and products between the United States and Mexico.
- The cooperation necessary to assure prompt transmission through telecommunications networks of these data and products.

Over the past few years, the Mexican Meteorological Service has undergone some modernization which included upgrading upper-air observation systems and installing Doppler weather radars. This cooperative agreement will facilitate the exchange of data and information to the benefit of both countries.